Cortical Control of Neural Prostheses

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Work Performed During the Reporting Period

In this reporting period, we continued to record spike data from our previously implanted monkey. Two animals were implanted this quarter with micro-wire arrays consisting of Teflon-coated stainless steel wires (50 microns in diameter) arranged in two linear arrays of eight wires each (spaced two hundred microns apart). The stainless steel electrode arrays were purchased from NB Labs. The prototype of a new type of electrode with a self-contained microdrive, displayed at the Neural Prosthesis Program Annual Meeting in September, was also implanted during this quarter. It consists of sixteen polyamide-coated 50 micron wire placed in a semi-lunate shape covering a total of 4mm in surface area. Also, two new monkeys were obtained and trained in this quarter.

We have been able to continue to record activity from the initial hemisphere of Monkey H seven months after surgery. Presently, there is still activity on up to twenty electrodes, with up to twenty-five units present on the side of the initial surgery. A second surgery was performed on the contralateral hemisphere, included the placement of an electrode with the self-contained microdrive. The most consistent recordings from this hemisphere have been from the prototype electrode. Units were able to be isolated at much shallower depths (~1mm from the cortical surface), and the electrical activity could be seen to change with the depths of the electrodes. (See Figure #1) The number of units that could be isolated was also seen to clearly depend on the depth of implantation, leading us to believe that variable depth devices hold promise for the future of chronic electrode recording.

Unfortunately, the initial surgery on Monkey J was not as successful as the previously mentioned one. During the surgery, the monitoring equipment was not felt to be working properly and was clearly giving erroneous information. Attempts to address this were unsuccessful, and the animal was unable to be weaned from the ventilator. Steps have been taken to remedy this situation from occurring in the future, including updating our monitoring equipment in preparation for the next surgery.

There continues to be multiple groups working on the analysis of this data. Our general thrust has been towards the use of neural networks and the use of the population vector approach to help derive a neural trajectory from this activity. There has been an effort over the past few months into investigating the addition of temporal features of the neuronal firing pattern to help to improve the consistency of the neural trajectories. To show that the temporal modulation of the neural ensemble can aid in improving accuracy, a principal component analysis has been developed. This analysis can use the pattern of co-activation of the ensemble to define the epoch of the task (whether the arm is in motion) as well as the instantaneous velocity of the hand during movement. Initial results have been presented at the Neural Control of Movement Meeting, and have shown this method to be accurate (in terms of target prediction) up to 75% of the time. Moreover, this method requires only minutes to train and can convert the cortical activity to a control signal in milliseconds. Based on these early results, we feel that the addition of temporal information to pattern recognition algorithms (such as the SOFM) may help to improve accuracy.

Another conversion algorithm is also being investigated, using fuzzy logic to relate discharge rate to the instantaneous velocity of the hand. Although the addition of

rules to the rulebase increases the time to train the system, it clearly helps to improve the accuracy of the derived trajectoreies. Best results from this currently can be found with averaged trials. (See Figure #2).

The real-time data collection apparatus, as described in previous reports, operates within a client/server architecture. Upgrading our internal network has allowed us to shorten the transmission time and has eliminated many of the real-time errors due to system delays. A real-time raster plotting program has been designed which records and displays raster plots in real-time from up to sixteen neurons. Future tests of the entire systems ability to respond for over progressively smaller timeframes will help to define the limitations of the network.

Dr Richard Stein, an international expert in the field of neural prostheses, spent two months of his sabbatical with us. His interest was in learning about the ability of multi-unit cortical activity to control a prosthesis, and in helping to define the issues which affect the consistency of long term cortical recording. We felt the interaction was mutually beneficial, as he provided for us invaluable insight into the process of prosthetic design and implementation into clinical trials.

Work anticipated for the Next Reporting Period

Improvements to our monitoring equipment should help to address surgical morbidity. Our data analysis will continue primarily along the lines mentioned above in order to extract directional information from the cortical signal. The testing of the improvement to the real-time system is helping to define the limitations of the system. Finally, we will continue be looking into the stability question in order to establish criteria for using a prosthesis over time.

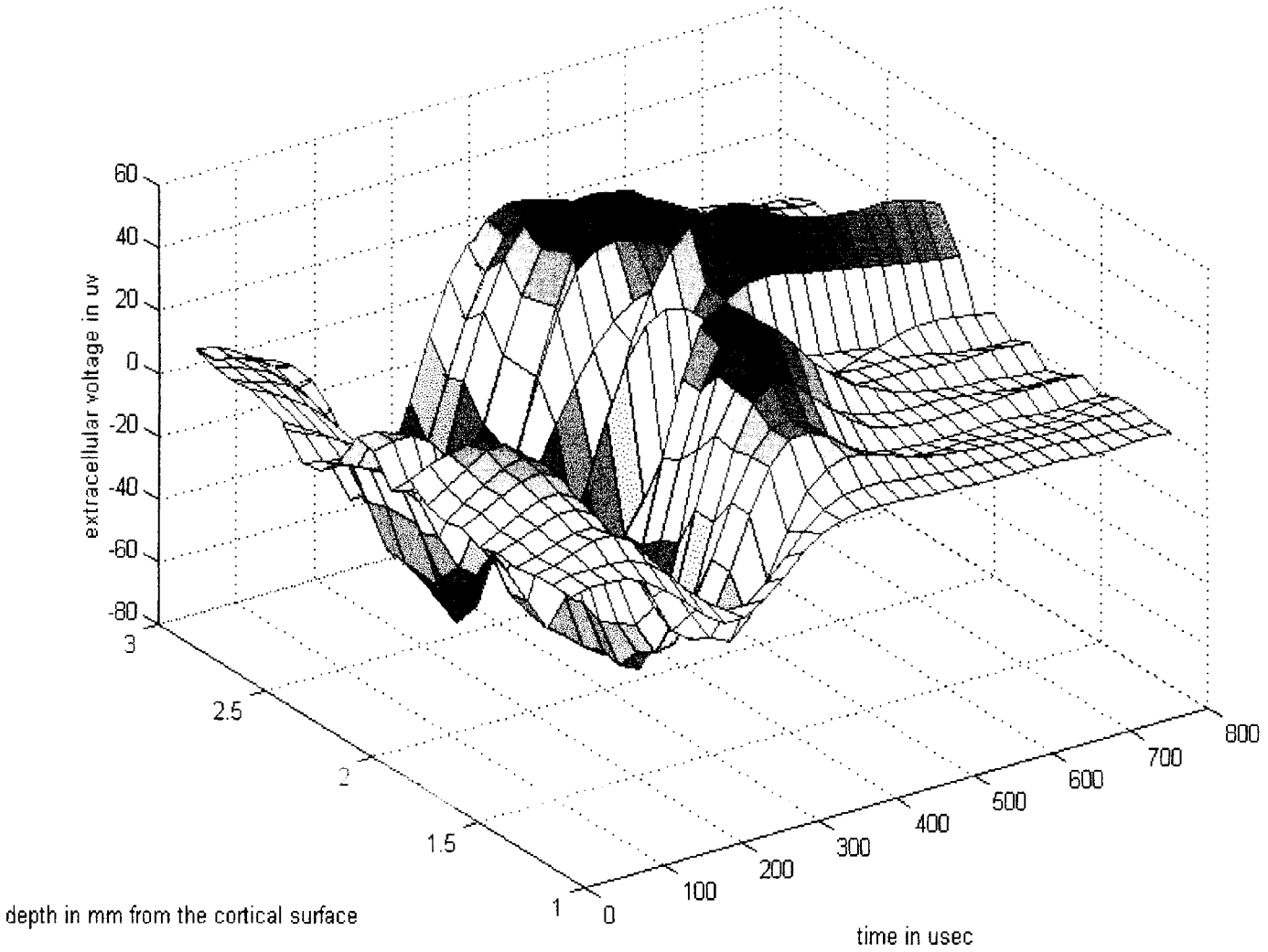

Figure 1 Averaged daily waveforms for one unit over five weeks as the electrode is lowered. Note how the extracellular potential increases to a maximum and then progressively decreases as the electrode is lowered.

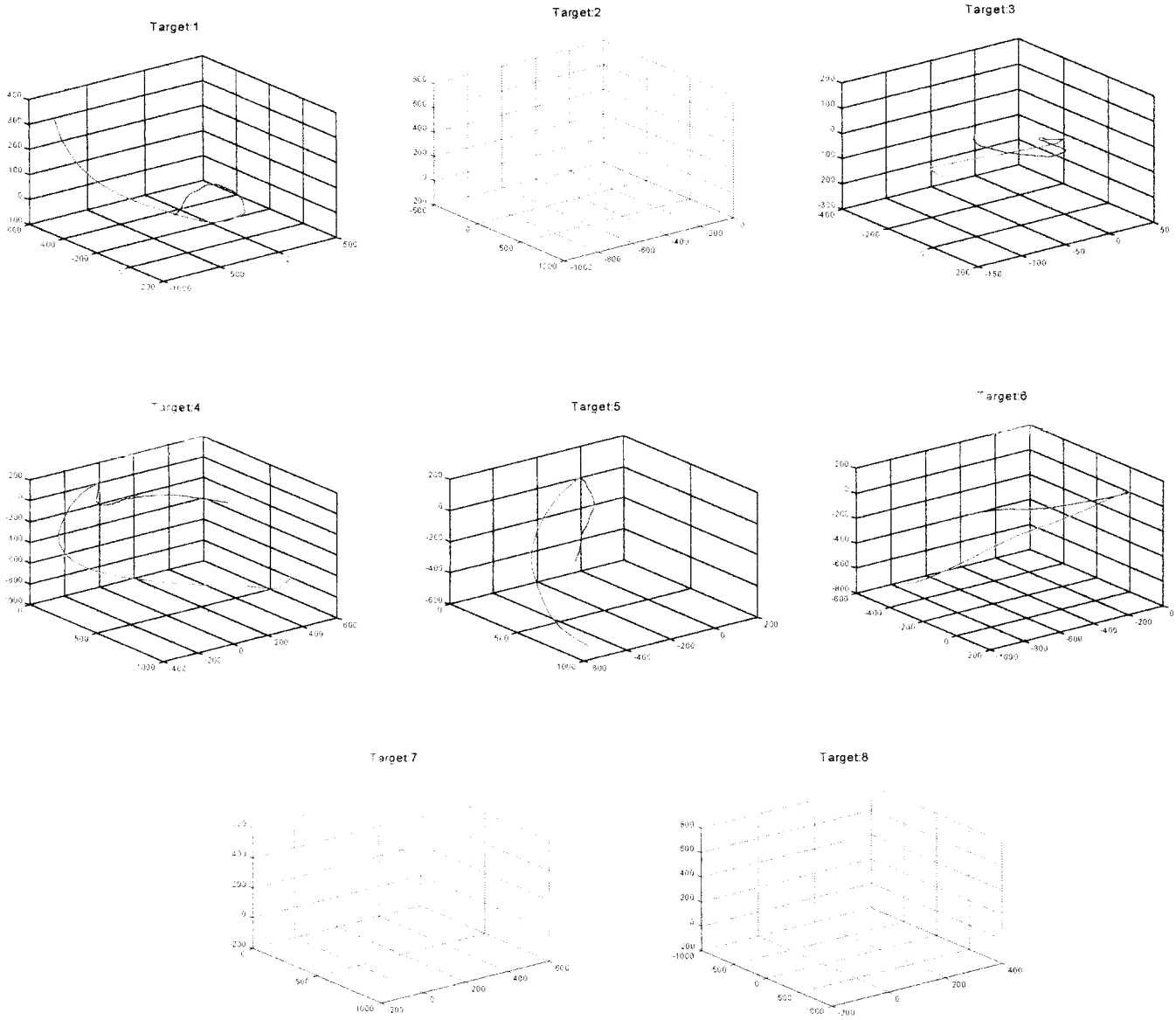

Figure 2. Results of the Fuzzy Logic Hand Velocity System using training from the average summary of 5 repetitions to eight targets of the first 4 data sets of a day and testing on the 5th set.